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DIFFERENTIATION OF CONDITIONED SPACE STIMULI

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DIFFERENTIATION OF CONDITIONED SPACE STIMULI

/Following is the translation of an article by P. S. Kupalov and M. M. Khananashvili entitled Differentsirovaniye Prostranstvennykh Uslovnykh Razdrazhiteley" (English version above) in Zhurnal Vysshey Nervnoy Deyatel'nosti (Journal of Higher Nervous Activity), Vol. 10, No. 3, Moscow, 1960, pages 305-312./

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Study of the higher nervous activity in animals under laboratory conditions such that the animals' motor activity is almost unlimited -- i.e., under conditions very closely approximating their natural freedom of activity -- made it possible to establish the fact that the behavior of animals is determined to a great extent by the space factor.

We understand "the space factor" to mean the spatial arrangement of conditioned and unconditioned stimuli, the location of the animals in relation to these stimuli and to other surrounding objects, and, in this connection, the movements of the animals in space. This factor is constantly operative not only under experimental conditions but under conditions of natural motor activity of animals and humans as well.

The study of the space factor, begun in 1942 in the laboratory of P. S. Kupalov, led to the establishment of a number of laws which are important in revealing the mechanisms of complex behavior reactions (Kupalov /11,12/). For example, it was demonstrated that if, in the section of the experimental chamber where the animal is located, a positive conditioned stimuli is introduced, that section becomes a positive conditioning agent and a factor which, together with other conditioning stimuli, determines the conditioned-reflex motor activity of the animal in the experimental chamber. If we combine the presence of the animal in a definite section of the experimental chamber

with an inhibiting conditioning stimulus, or if we effect a damping of a spatial positive conditioned reflex, then this section of the chamber acquires for the animal a negative, inhibiting significance (Yakovleva [15], Voyevodina and Kupalov [6], Gordeladze [7]).

The significance of the spatial arrangement of conditioned sound stimuli in the experimental chamber was demonstrated, and certain conditions were elicited which lead to the impairment of higher nervous activity upon spatial transference of these stimuli (Kudryashova [10].

Experimental data which indicate the importance of the spatial factor in conditioned-reflex motor activity were obtained also in the studies of V. M. Kas'yanov [9], I. M. Apter [2], I. S. Beritov [4], E. Sh. Ayrapet'yants [1].

In order to effect further studies of the spatial factor, we have investigated the physiological significance of the conditioned space stimulus for various spatial orientations of an animal in an experimental chamber.

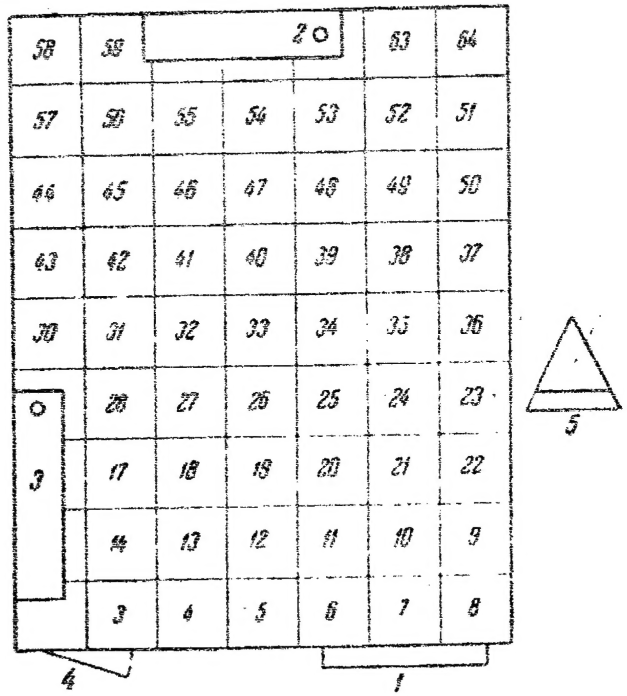
Methods

Experiments were conducted on the dogs Buyan and Pal'ma in a large experimental room in which were placed two tables with feed boxes. The floor of the experimental room was divided into squares which were numbered to facilitate observation of the movements of the animals (see scheme).

The animals were observed through a window in the rear wall of the experimental chamber from a small room adjacent to the experimental chamber.

During the experiment the animal was completely isolated from the experimenter and the entire conditioned-reflex activity was developed only by means of conditioned and unconditioned stimuli switched on by the experimenter from his observation point.

The conditioned reflexes were developed as follows: at the start of the test, pieces of meat were scattered on the floor, making a path leading to the table with the feed box. The dog picked up the pieces of meat and, following the "meat route," climbed the table to the feed box where he ate a meat-biscuit powder placed in the feed-box cups. Having finished eating, the dog usually went down to the floor. As a result of several trials combining the clatter of the feed box became a conditioned stimulus causing the dog to run to the feed box. By combining various conditioned stimuli with feeding we created



Scheme of the experimental room:
1 -- experimenter's observation chamber, 2 -- table with feed box, 3 -- second table, 4 -- entrance door, 5 -- shelf with metronome.

conditioned reflexes to corresponding stimuli.

As a conditioning sound stimulus we employed a metronome which was placed on a shelf on the right wall of the experimental chamber. As a conditioning optical stimulus we employed a 55 watt electric lamp which was placed on a stand in front of the feed box. Reinforcement was produced with the feed box on the second table (see scheme).

Results of Studies

At first, following the development of a reflex response to the sound of the metronome, the dog Buyan in the experimental chamber behaved in a confused manner: in the intervals between conditioned stimuli the dog walked rapidly or ran in the room without stopping anywhere for any length of time. Subsequently, the conditioned stimulus -- the metronome -- was switched on several times when the animal accidentally crossed square 22. After a few trials of the metronome in conjunction with the presence of the dog on this square, one could observe that during the interval between the stimuli the animal settled himself most frequently on square 22. When, in further tests, the metronome was switched on, the dog ran to the feed box on the second table, ate a portion of meat-biscuit powder and walked toward square 22 where it remained (upright, or sitting, or lying) till the next sounding of the metronome. Thus a definite area of the experimental floor (square 22) was transformed into a segment of space where the dog settled in the intervals between the conditioned stimuli.

However, in a number of instances the dog did not return to square 22 after eating, but commenced to walk on various squares for 30 to 60 seconds, and only then returned to square 22. One day the metronome was switched on precisely at the moment when the animal, having eaten its usual portion of meat powder, did not go directly to square 22 but started to walk on different squares. The metronome was switched on when the dog was crossing square 46. At the sound of the metronome the dog stopped at once, and turned his head in the direction of the metronome sound; a distinct orientation reaction was observed. At this point, despite the continued sounding of the metronome, the dog failed to respond with the conditioned reflex of running to the table and feed box (Table 1).

Subsequently the metronome was switched on without food reinforcement each time the dog passed over square 46. Already in the second trial with the metronome when

Table 1

Dog Buyan, 6 June 1955

1 Интервал между раздражителями в мин.	2 Число сочетаний	3 Условный раздражитель	4 Время изолированного действия условного раздражителя в сек.	5 Латентный период условного рефлекса в сек.	6 Поведение собаки на условный раздражитель в интервале между условными раздражителями
	29	7 Метроном	5	1	8 Подбегает к кормушке. После еды становится на квадрат 22
2					
	30	»	5	1	9 Подбегает к кормушке. После еды медленно ходит по разным участкам комнаты, при положении на квадрате 46 включается метроном
1					
	1	»	20	—	10 Ориентировочная реакция, смотрит на источник звука, по сторонам. Через 1 мин. стоит на квадрате 22
2					
	31	»	5	1	11 Подбегает к кормушке. После еды ходит по разным участкам комнаты. При положении на квадрате 46 включается метроном
1					
	(2)	»	10	3	12 Слабая ориентировочная реакция, подбегает к кормушке. Еду не поедает. Стоит у кормушки 10 сек. и направляется к квадрату 22
2					
	32	»	5	1	13 Подбегает к кормушке. После еды идет к квадрату 22

14 Примечание. В скобках указывается число применений метронома при нахождении собаки на квадрате 46.

/Continued on next page/

/Continued from page 5/

1. Interval between stimuli, min.
2. Number of trials.
3. Conditioned stimulus.
4. Duration of the isolated action of conditioned stimulus, sec.
5. Latent period of the conditioned reflec, sec.
6. Behavior of dog in relation to the conditioned stimulus during the interval between conditioned stimuli.
7. Metronome
8. Dog runs to the feed box, and after eating stands on square 22.
9. Dog runs to feed box, and after eating walks slowly all over the room; when dog stands on square 46, the metronome is switched on.
10. Orientation reaction; dog looks in the direction of sound and in various other directions. A minute later he stands on square 22.
11. Runs to feed box. After eating, walks all over the room. Metronome switched on when dog crosses square 46.
12. Weak orientation reaction, runs to feed box. Does not eat. Stands near feed box for 10 seconds, then goes to square qq.
13. Runs to feed box. After eating, goes to square 22.
14. Note: The number of metronome signals when the dog was on square 46 is indicated in parentheses.

Subsequently the metronome was switched on without food reinforcement each time the dog passed over square 46. Already in the second trial with the metronome when the dog was on square 46, there was a weakening of the orientation reaction; subsequently the dog was observed to run to the feed box every time the metronome sounded when he was on square 46, even though no reinforcement was employed.

Subsequently the metronome was switched on once or twice during each day of the experiment, when the dog happened to be on square 46. It always induced the dog to run to the feed box. Starting with the 13th trial of the metronome with the dog on square 46, there was observed an increase of the latent period before the run to the feed box. At the 18th trial of the metronome there was observed for the first time a complete absence of movement toward the feed box; the dog stopped, looked for three seconds at the feed box or in the direction of the metronome, and then moved slowly over squares 47-48-49-37-23 toward square 22

Table 2

Dog Buyan 2 July 1955

1 Интервал между раздражителями в мин.	2 Число сочетаний	3 Условный раздражитель	4 Время изолированного действия условного раздражителя в сек.	5 Латентный период условного рефлекса в сек.	6 Поведение собаки на условный раздражитель и в интервале между условными раздражителями
	125	7 Метроном	5	1	10 Подбегает к кормушке. После еды становится на квадрат 22
3	126	»	5	1	11 То же
2,5	65	8 Свет	5	1	12 Подбегает к кормушке. После еды ходит по разным участкам комнаты. При прохождении по квадрату 46 включается метроном
1,5	(18)	9 Метроном	10	—	13 Смотрит на кормушку, на метроном, через 3 сек. направляется к квадрату 22 по квадратам 47—48—49—37—36—23
	127	»	5	1	14 Подбегает к кормушке. После еды становится на квадрат 22
1	128	»	5	1	15 То же

Legend continued from page 7

1. Interval between stimuli, min.
2. Number of trials
3. Conditioned stimulus
4. Duration of isolated action of the conditioned stimulus, sec
5. Latent period of conditioned reflex, sec
6. Behavior of dog in relation to the conditioned stimulus and in the interval between conditioned stimuli
7. Metronome
8. Light
9. Metronome
10. Dog runs to the feed box, and after eating stands on square 22.
11. The same
12. Dog runs to feed box, and after eating walks in various sections of the room. When he crosses square 46, the metronome is switched on.
13. Dog looks at feed box, at metronome, and after three seconds walks to square 22 via squares 47-48-49-37-36-23.
14. Dog runs to feed box. After eating, stands on square 22.
15. The same

(Table 2). With the 22nd trial of the metronome a complete differentiation of the spatial area 46 from area 22 took place: The dog upon hearing the conditioned sound stimulus, ran to the feed box if he was standing on square 22 but not if he was on square 46.

In further tests we began to induce differentiation of a new location, as related to square 22. This time the metronome was switched on without reinforcement as soon as the dog passed square 52. At the very first use of the metronome, the dog went at once to the feed box but, then having received no food, went and stood on square 22. A similar reaction was observed during subsequent experimental days, when the metronome was switched on as the dog was crossing square 52. Starting with the 10th use of the metronome, there was an increase in the latent period before running to the feed box when the dog was on square 52 and, starting with the 11th trial of the metronome, the conditioned reflex of running to the feed box was completely absent. At the same time the dog

upon hearing the metronome when he was on square 22, ran at once to the feed box.

Our next task was to induce the dog to differentiate another spatial area -- square 18 -- from square 22.

The very first trial of the metronome with the dog on square 18 caused a definite orientation reaction: the dog looked immediately in the direction of the metronome sound, then at the feed box, made two steps toward the feed box, and stopped. A similar reaction was observed in the second trial when the dog was crossing square 18. However, starting with the third metronome sound, the dog began to run to the feed box despite the fact that the stimulus of the metronome with the dog on square 18 was not reinforced with food. However, already at the 10th use of the metronome, the dog ceased running to the feed box when the sound reached him on square 18. In this case, too, the positive conditioned reflex to the metronome sound when the dog was on square 22 was preserved without alteration. Thus, Buyan learned to differentiate between identical sound stimuli given when he occupied two different spatial positions in the experimental chamber.

It was observed during the development of differentiation between various sections of the room that switching on the metronome while the dog was in the "negative" spatial areas caused him to cross over to the "positive" square 22; i.e., if the dog was on squares 46,52 and 18, he crossed to square 22 in response to the metronome sound. At first this reaction was irregular and slow, but with the strengthening of differention the dog quickly left the negative area and ran to square 22.

Another phenomenon was observed following the development and strengthening of differentiation: As soon as the dog found himself on the "negative"square, he did not wait for the metronome sound but left the area and crossed to square 22; i.e., the very location of the dog in "negative" areas incuded him to cross to the "positive" area.

Thus, following the development of positive and negative conditioned reflexes, the experimental chamber became for the dog a region consisting of "positive and "negative" areas, a fact which has important significance in the behavior of the animal.

In the dog Pal'ma there was developed a positive conditioned reflex of running to the feed box in response to the lighting of an electric lamp and to the sound of a metronome. Following the strengthening of a previous conditioned stimulus with meat-biscuit powder, the dog went each time to square 39 and remained there till the next conditioned stimulus.

Having strengthened this activity, we set about to eliminate the conditioned reflex to light and thus to induce a marked change of the entire behavior of the animal in the experimental chamber. At the beginning of damping the conditioned reflex to light, the animal commenced to avoid square 39 and stopped not far from this square; after repeated light stimuli without reinforcement, the dog began to run from the front to the rear of the room or to the door, or climbed the second table and stood on it till the conditioned sound stimulus was given. Prior to the damping of the conditioned light reflex, the dog had never climbed the second table.

Discussion of Results

If we reinforce a conditioned sound stimulus with an unconditioned food stimulus at a definite location of the animal in the experimental chamber and do not reinforce the same stimulus at another location of the animal, we can induce the animal to differentiate between identical sounds depending on his location in the experimental chamber.

The first stage of differentiation consists of the dog's orientation reaction to the use of a conditioned sound stimulus when he is at an "unusual" location in the experimental chamber. After repeated use of the sound stimulus at the unusual locations, the orientation reaction weakens and the second stage of differentiation takes place: the animal runs to the feed box from the "usual" as well from the "unusual" location.

The second stage of differentiation is characterized by a generalization of the spatial conditioned reflex, as a result of which the location of the animal in a new spatial area acquires the same alimentary physiological significance. After several trials of the metronome without reinforcement, at the "unusual" location of the animal, the third and final stage of differentiation takes place: identical sound stimuli now have a positive or negative significance depending on the location of the animal.

Apparently, differentiation is effected on the basis of inner inhibition developing in response to a complex stimulus which includes sound and spatial factors, the spatial factor playing the determining role under the circumstances.

The development of differentiation of spatial factors has much in common with the development of differentiation of other stimuli studied in the I. P. Pavlov laboratory /14/. Thus, for instance, the stages of

development of differentiation of areas coincide with those observed in work with other stimuli (Belyakov [3]).

Following the development of differentiation of areas, the use of a conditioned sound stimulus at an "unusual" location causes the animal to run away from a given area in the room. An analogous phenomenon was observed by P. S. Kupalov [12] during the development of differentiation of two different sound stimuli; upon the use of a differentiated sound, the dog would quickly leave the occupied section of the room and run to another section. A similar reaction was observed during the differentiation of conditioned optical stimuli into an inhibition stimulus (Kupalov and Khananashvili [13]). The biological significance of this reaction is apparently that the animal defends itself from the nervous reaction which develops in the central nervous system in response to an inhibition stimulus connected with the absence of food.

Regarding the nervous mechanism of this reaction, it is of interest that very often running away from a "negative" section of the room is connected with crossing to the "positive" section of the room, which has a positive alimentary value. This phenomenon, observed also by other authors (Yakovleva, Gordeladze), indicates definite induction relationships between spatial conditioned reflexes developed under given experimental circumstances.

Following the development of a stable differentiation of areas, the mere location of the dog in "negative" areas sometimes induced a motor reaction directed toward transfer to a "positive" area, -- i.e., location in definite areas, without any supplementary stimuli, leads to purposeful motor activity.

The factual data accumulated thus far enable us to assume that very complex and lengthy nervous processes, involving many components, constitute the complex conditioned-reflex activity of animals. These components, determined by the conditioned stimuli employed as well as by the location of the animal in space, its posture, motions, etc., are unified into a complex, organized, functional structure in the higher centers of the cerebrum and, in their interaction, determine one or another extermal reaction. One may assume, in particular, that the inhibition of one area in the functional structure of a nervous process induces, by means of positive induction, the excitation of other links functionally connected with the inhibited point. One concrete example of such nervous activity is the crossing of the animal from the negative area of the room into an area which has positive

alimentary value.

For further study of the spatial factor and its importance in the behavior of animals, it is essential to ascertain which nervous structures participate in the development of spatial conditioned reflexes.

I. S. Beritov [5] has demonstrated the important part played by optical and especially labyrinthine stimuli in the orientation of animals and humans in space. A. I. Yemchenko [8] points out the importance of the kinesthetic factor in the evaluation of spatial relationships.

In the studies of Neff, Fisher, Diamond and Jela [16] there is noted the impairment in cats of a correct spatial perception of sound stimuli after the removal of the auditory area of the cortex. Obviously the leading role in the spatial orientation of animals belongs to the cortex of the large hemispheres.

The spatial factor participates constantly in the conditioned motor reflex activity by virtue of formation of spatial-temporal connections and, together with conditioned and unconditioned stimuli it determines this activity. This factor [should be the] subject [of] physiological analysis based on the general laws of higher nervous activity.

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